Boundaries in the Protection of Nature Reserves

Translating multidisciplinary knowledge into practical conservation

Christine M. Schonewald-Cox

In most countries of the world, natural habitats are on the decline. To avoid indiscriminate land use and to allow evolutionary and ecological processes to function naturally, land has been set aside as national parks, reserves, forests, refuges, and recreation areas, which I refer to collectively as nature reserves.

These nature reserves can serve as a baseline against which environmental change in adjacent areas can be measured. If, in addition, nature reserves are to protect biodiversity for the future, local human communities must be considered in nature reserve planning, design, and management (see Dasmann, page 487 this issue). Analyses of nature reserve protection should combine anthropocentric disciplines, such as economics, law, and anthropology, with the biological ones to reach a powerful multidisciplinary synthesis (Anadu 1987, Field and Johnson 1981, Forman and Godron 1986, Ives and Ives 1987, Janzen 1983, Myers 1987, Norton 1986, OTA 1986, Prims 1987, Sax and Keiter 1987, Risser 1985, Schonewald-Cox et al. 1983, Soulé 1986, Usher 1986, Wilson 1988).

There is a great gap between what has emerged from basic research and what nature reserve managers need for planning and evaluation of protection. Therefore, considerable attention is being given to translating the multidiscipline knowledge base into practical conservation terms (Diamond et al. 1987, Field and Johnson 1983, Keiter and Hubert 1987, Loomis 1987, Lucke 1986, Machlis and Tichnell 1987, Quinn in press, Salwasser et al. in press, Schonewald-Cox 1983, Soulé 1986, 1987, Wilcove and May 1986, Wilcox in press). In an effort to broaden and accelerate information transfer to protection of nature reserves—and guide their planning, design, and evaluation—my colleagues and I have proposed an approach that focuses on the reserve boundaries (Schonewald-Cox and Bayless 1986).

We can treat the boundary as a skin, whose condition can indicate the health of the entire system

In this article, I describe the perspective for this work, review the premises of the boundary approach, and provide an example of how it is being developed. Finally, I present a few thoughts on its potential uses.

Perspective

Success in protecting nature reserves is affected by more than the ecological characteristics within reserves. All nature reserves interact with their surroundings. While populations of some species may be genetically isolated, others incorporate genes or individuals from populations outside the reserve. However, most concern focuses on the direct and indirect "impacts"[1] of people (O'Leary 1987). These impacts include trampling of meadows by reserve visitors, poaching, invasion of exotic species, and acid rain.

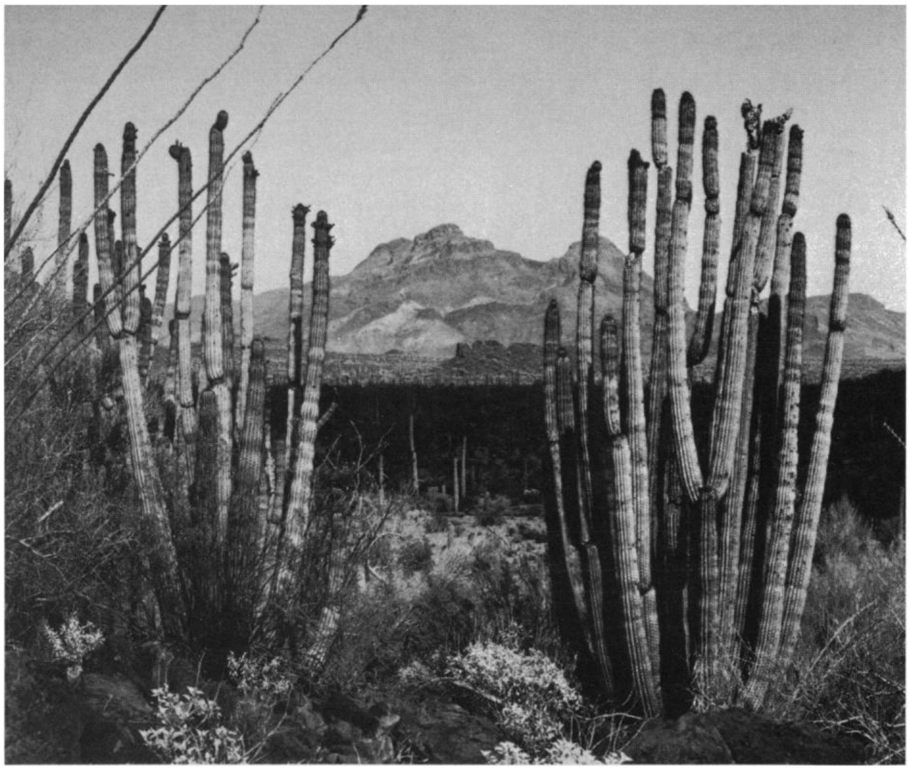
Long-distance effects on reserve protection, for example, include changes in laws, administrations, economies, and political systems. More local effects include the attitudes of owners of adjacent land and the strength and consistency with which the reserve is protected. If the protective regulations are not adequately enforced, protection is subject to the will of the public, which may or may not comply. Decades or centuries of investment in protection can be easily lost if regulations stop being enforced. Ideally, an interdependence develops between the reserve and the public, making protection less difficult.

Energy investment in protection

Energy is required to maintain land in a specified condition, and the demand for invested energy increases with the degree of contrast between protected and nonprotected conditions. If the surrounding habitat is disturbed and receives less or no protection, the nature reserve will likely also change towards this state unless strict countermeasures are taken (Ambrose 1987, Diamond et al. 1987).

Christine M. Schonewald-Cox is a research scientist at the Cooperative National Park Studies Unit, Ecology Institute, Wickson Hall, University of California, Davis 95616.

[1] *Impact*, in resources-management terminology, usually bears negative connotations.



The organ pipe cactuses lend their name to the Organ Pipe Cactus National Monument. Photo: National Park Service.

Energy is invested by means of management, enforcement, public relations, legal actions, and other activities on behalf of protection. If managers receive the cooperation of reserve users, visitors, and neighboring communities, less enforcement and management energy will be required to achieve successful protection than without cooperation. If the nature reserve is in conflict with a neighbor over an issue, and the neighbor exerts more local or national influence, the reserve is likely to change towards the neighboring condition.

Energy can also be used to restore habitats to more desirable states, as determined by the objectives of protection. Some possible objectives are species diversity, increasing populations of particular species, or exemplifying a specific ecosystem. Owners of adjacent land are likely to put energy into achieving objectives they see as desirable. These efforts may work synergistically with those intended to protect the nature reserve, or they may be in conflict. A pervasive management problem is that the desired condition of a reserve is often not adequately specified by those responsible for setting aside the area.

Energy translates into forces that support or undermine protection. The outcome of these forces' interaction across the reserve boundary determine where the functional divider lies between the nature reserve and the surrounding region.

The boundary model

My colleagues and I have been drawn to the study of reserve boundaries because of their major role in protection, including determining species viability, which ultimately determines species richness. As the nature reserve interacts with its surroundings, the boundary is a zone of activity and change. We can treat the boundary as a skin, whose condition can indicate the health of the entire system. Like a skin, the boundary functions in two dissimilar environments, protecting one environment from the other.

Because the boundary of the reserve, as it is administered, may be complex, under legal debate, and include inholdings and planned transfers of ownerships, I use the term *administrative boundary*. The administrative boundary is what those responsible for the reserve consider the limits of their current authority (Figure 1). The administrative boundary of the nature reserve can serve as the geographic line for comparison of conditions inside and outside the reserve. The administrative boundary and ecological boundaries (habitat changes) associated with protection are distinct from each other. Thus, ecological or landscape demarcations may not necessarily coincide with the administrative boundary.

As a first step in the analysis of protection, focused upon the boundary region, we need a means to organize and integrate information from the multiple disciplines that are required to describe the region. To this end, we developed our boundary model (Schonewald-Cox and Bayless 1986). Our use of it helps us to incorporate as many disciplines (including anthropocentric ones) as are appropriate. What is appropriate is determined by the specific purpose and characteristics of the nature reserve and its surrounding area.

The boundary model keeps the focus of our analysis in the region of the administrative boundary and from there provides a framework for analysis of protection. Modern methods of remote sensing, spatial analysis, and geographic information systems are easily applied to this type of boundary analysis. We map such properties as vegetation type, water abundance, social units, and local economic conditions as we would for any ecological or landscape analysis. And, similarly, we search for consistent patterns that offer insight into the behavior of the system.

Properties of the boundary region. In studying a boundary region, we can focus on physical dimensions including the length, width, depth, or height of the boundary zone; its subdivisions; and associated characteristics. Over time, the spatial and functional relations change, forces interact, and energy balances shift. These processes have already been described for ecological transitions and landscape features (Ambrose 1987, Forman and Godron 1986, McCoy et al. 1986, Noss and Harris 1986).

These specific properties of nature reserve boundary regions are likely to vary depending on the location, resolution, and characteristics of protection. Spatial, functional, energy, and temporal relations between variables associated with the boundary region of the nature reserve are major determinants of short-term and long-term protection effectiveness.

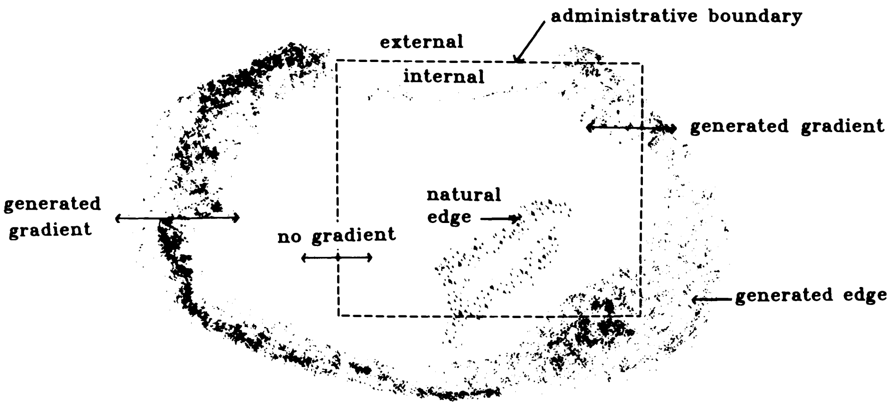


Figure 1. Schematized illustration of a reserve boundary region (Schonewald-Cox and Bayless 1986).

The first filter. The administrative boundary can be considered as a filter that separates people who are inside the nature reserve, and subject to the regulations of protection, from those who are outside. This first filter is not physically tangible. Animals, plants, soil, air, and water do not respond to regulations. The manifestations of this filter are due to the human response.

People who pass through this first filter respect protection and obey the regulations, whether or not they perceive the significance of regulations or agree with them. People not intending to comply with regulations are blocked by the filter. Noncompliance or ignorance that results in breaking of regulations represent a rupture of the filter. Enforcement, explanation, and other public education sustain the filter. Attempts to apprehend offenders and increase public interest in park values encourage obedience. Thus, as a second step in the analysis of protection, we evaluate how effectively the first filter works (i.e., its condition).

The generated edge, a second filter. In our description of the boundary, we proposed an edge that is the manifestation of the biological, anthropological, and physical habitat changes caused by the response of people to the first filter. The generated edge is distinct in that its location and characteristics develop in response to the condition and effectiveness of the first filter. This edge, generated by protection, also affects protection. It includes ecologic, geologic, climatic, economic, and demographic gradients, such as varying land-use practices. This generated edge functions as a filter, variably permeable to biotic and physical features based upon the structural characteristics of the nature reserve and the surrounding landscape. The generated edge may overlay and modify both natural and man-made edges that were present before protection was planned or established. Or the generated edge may be a new modification, introduced by the protection, where no edges previously existed. Locating and determining the condition of a generated edge provides an indication of the effectiveness of protection and guides the application of measures to increase locally the protection at the reserve boundary.

Various specific information can be included in the description of the generated edge. The marked contrast in habitat conditions, for example, seen when entering an urban park or a protected forest fragment (Figure 2) is a superficial view of the vegetation's generated edge. However, the generated edge can be more complex and difficult to identify.

The generated edge and birds' reproductive successes. Edges of bird habitats can be subtle. Temple and Cary (in press) conducted a 12-year study of fragmented habitats in southern Wisconsin. By also using 60 additional years of historic data and Brittingham and Temple's (1983) data on demography and fecundity of species that require forest-interior habitat and on landscape characteristics of Wisconsin forests, they modeled breeding success of bird species in fragmented forests of variable sizes.

Interior bird species were found in most Wisconsin forest fragments, but the presence of a species does not accurately reflect nesting of the birds. Within 100 meters of the fragment borders, nesting success of 16 interior bird species was as low as 18%. Between 100 and 200 meters nesting success increased to 58%. At greater distances from the border, nesting success increased to 70%. In the simulation, only the few fragments with areas greater than four square kilometers had nests of more than one pair of interior birds. If these fragments were protected with their administrative boundaries coinciding with the forest edges, the generated edge for forest-interior bird species would extend inward a minimum of 100 meters. (This edge effectively reduces the sizes of the protected fragments by $2\pi\ [r - 100 \text{ meters}]^2$ for equivalent round fragments.)

A similar example could be drawn from Wilcove's (1985) studies of migratory songbirds. Therefore, a third major step in the analysis of boundary effectiveness is finding where the generated edges are for priority concerns, such as bird habitats, and determining how they are changing or likely to change with respect to the administrative boundary.

Dynamic processes affecting the generated edge. Changes in the first filter, such as changes in regulations, enforcement, or human respect for the regulations, directly affect the generated edge. In addition, the generated edge responds to natural changes in its ecological parameters. The location of the generated edge is expected to change with time. Its spatial relation to the administrative boundary is also likely to change along, as well as across, the perimeter.

Areas within a nature reserve can contribute to the condition and location of generated edges. The internal impacts of too many visitors to geysers, meadows, trails, or camping areas create edges. These impacts can counter protection measures within the reserve, affecting, for example, species movements and survival. Unwise management and enforcement also increase the likelihood that the generated edge will extend further into the reserve. Heavily used roads and trails can effectively cut the nature reserve into two or more fragments, equivalent to smaller nature reserves.

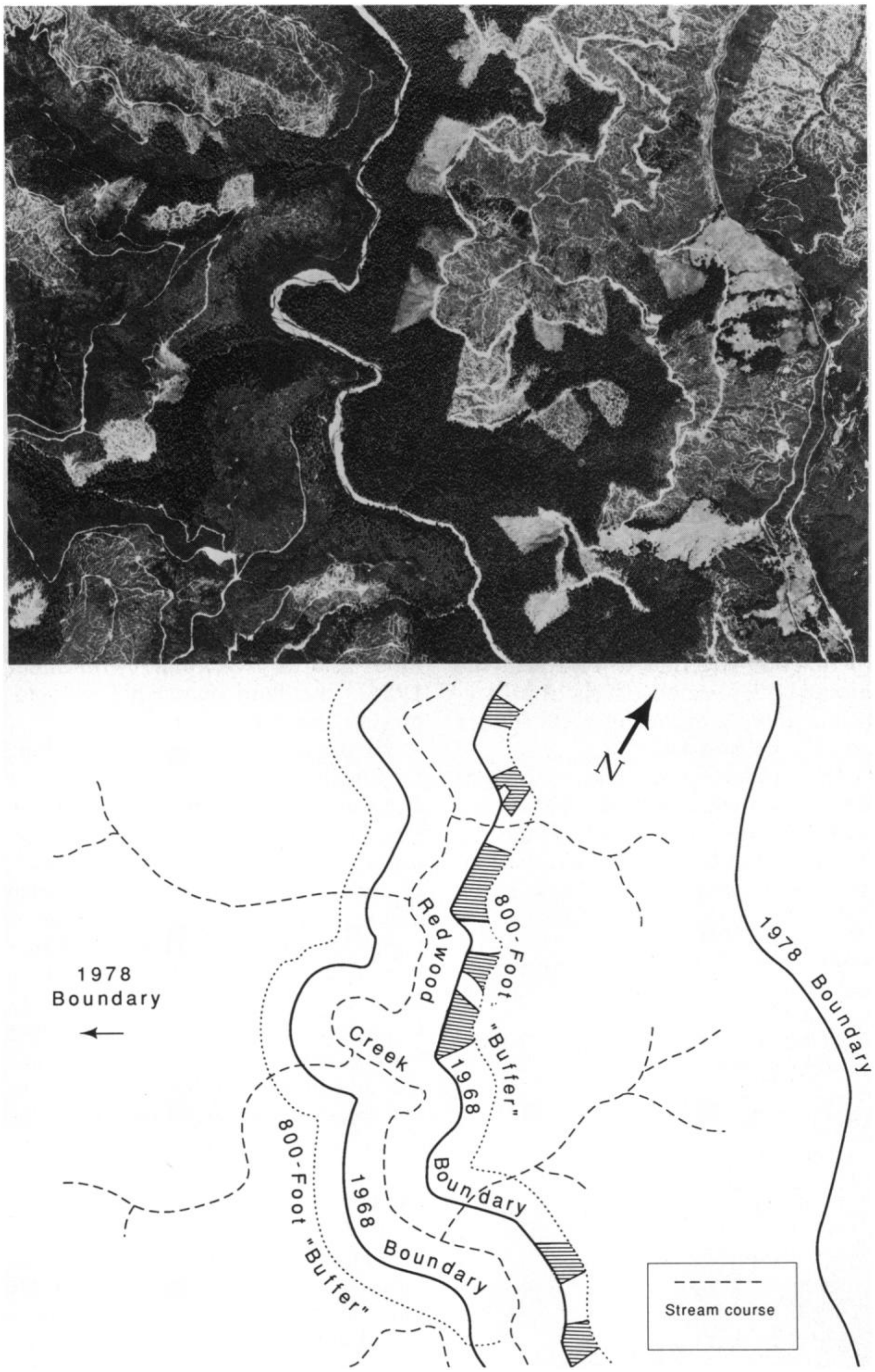


Figure 2. (Top) Aerial photograph of Redwoods National Park, California, illustrating abrupt limits of deforestation. (**Bottom**) When Redwoods National Park was first set aside in 1968, an informal buffer 800 feet wide was agreed upon between the park and the owner of adjacent land to the east. There was to be no logging within this buffer. Later when it was proposed that the park would be expanded to the adjacent ridge-tops of redwood creek drainage (1978 boundary on the map), the owner of adjacent land began deforestation within the buffer zone. The park, which now extends to the 1978 boundary, has inherited these large tracts of deforested habitat. The generated edge within the park was created by the destruction of the agreed-upon buffer in response to the change in park planning. The edge includes vegetation, however the abrupt limits of logging sharply illustrate the vegetation-generated edge (dark areas). In the schematized drawing, the hatched areas within the 1968, 800-foot buffer are deforested patches. White areas within this zone are forest patches. (Photograph courtesy of S. Viers, Redwoods National Forest).

This increase in surface exposure has serious implications for protection.

Generated edges are more than "functional" boundaries or filters. They can attract or repel species (or people or activities); provide corridors for movement; generate populations of species (or provide for increases in human survival); prevent the reproduction or survival of species; and act as isolating boundaries. Changes in regulations, administrations, or management should be expected to have an impact on the characteristics of the generated edge.

Segmentation. The administrative boundary of a nature reserve is likely to be heterogeneous along the perimeter in its landscape, ecological, anthropologic, and economic characteristics, as well as in protection and land-use activities. Therefore, to analyze the boundary, we can divide it into segments for practicality. The number and size of segments is determined by the heterogeneity of the landscape and the scale of the analysis.

Segmentation is used in boundary analysis to designate localized differences in land ownership or use, in addition to biological differences. Repetition of similar types of segments along the full perimeter of the nature reserve facilitates management planning. Different types of segments may have predictable types of generated edges, and predictable rates of change for key variables. For example, the ecological gradients may be characteristically steep and narrow for one segment class. Those segments may be sites of predictable losses of species (or gains of undesirable ones) and have similar requirements for management, inventory, monitoring, and regulation enforcement. Note, however, that not all segments within a class are likely to be at the same stage of predicted change. The generated edges of all the boundary segments collectively describe the generated edge for key variables and indicate the effectiveness of protection of the administrative boundary at a given time.

The value of segment identification may appear to be dubious when one is studying only vegetation or animal life. But, when one begins to overlay analyses of visitor use, management specifications, resources management, water use, and local economic struc-

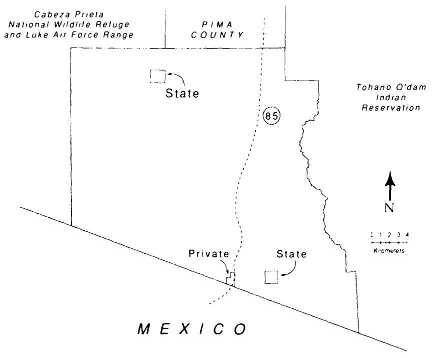


Figure 3. Organ Pipe Cactus National Monument, showing highway 85 (dashed line), state and private inholdings, and adjacent land ownerships.

tures upon numerous vegetation types and animal species, the value is more clear. Therefore, a fourth, major, step in the analysis of boundary effectiveness is determining which segment classes have the greatest importance for indicating, maintaining, and improving the quality of protection, and locating them in the reserve.

Organ Pipe Cactus National Monument project

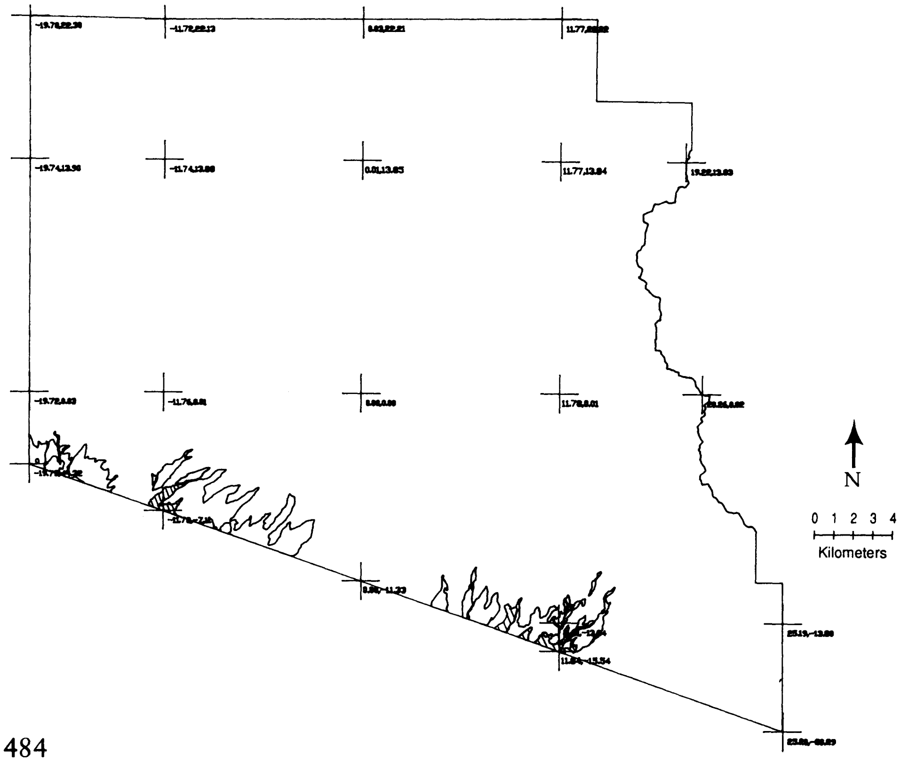
To apply our approach to boundary analysis for the study of reserve protection, we began several pilot projects. I briefly describe the first project here.

At Organ Pipe Cactus National Monument in Arizona, our study is using the boundary model to determine gradients and locate the generated edge and its boundary segments. The park managers are interested in mapping the administrative boundary and identifying sensitive habitats. These interests are part of the park's larger project—a baseline inventory.

The reserve. The Organ Pipe National Monument project examines a nature reserve in the context of its designated status as an international biosphere reserve (Risser and Cornelison 1979). This biosphere reserve consists of a pair of parks, Organ Pipe Cactus National Monument in Arizona, and Pinacate National Reserve, in Sonora, Mexico. These reserves are intended to function together to represent the biome under various levels of protection and types of management (Risser and Cornelison 1979).

Organ Pipe Cactus National Monument is neighbored in the United States by a national wildlife refuge, the Tohano O'Odam Indian Reservation, and Pima County land. Most of its Mexican boundary lies next to agricultural lands that are less restricted in use (Figure 3). Organ Pipe Cactus National Monument is bisected by a freeway, which may affect the reserve. Fragmentation effects will be examined in the study.

Figure 4. Organ Pipe Cactus National Monument administrative boundary and mapping coordinate system. The map of vegetation types located at the administrative boundary between the monument and Mexico is shown. Hatched areas represent vegetation types located only at this boundary. Originally mapped by Warren et al. (1981).



Data entry. We began by encoding available data for computer use and conducting a preliminary analysis with two geographic information systems: SAGIS and GRASS (American Farmland Trust 1987).[2] Our analysis is constrained by the limited information and the levels of data resolution available. Detailed faunal, land-use, and sociological studies are underway but still incomplete. Because the most complete data currently available for the park are maps of vegetation types (Figure 4), a soil survey (USDOA/SCS 1972), land classifications (Organ Pipe Cactus National Monument 1985), and land ownership, we emphasize these in the analysis.

We began our work by establishing a coordinate system for mapping the administrative boundary of Organ Pipe Cactus National Monument (Figure 4). Each patch of a characteristic vegetation type is outlined and called a polygon. Each vegetation type is temporarily assigned a layer, such that all polygons on one layer belong to the same vegetation type. There are 27 layers of vegetation types, one layer for the coordinate grid, and one for the administrative boundary. Other variables are similarly entered into the system and manipulated.

Data analysis. First, we examine the coincidence and mutually exclusive properties between vegetation types, landscape, and other factors. We are particularly interested in trends associated with the boundary. Second, we ask whether there are typical or predictable behaviors for polygons of each type of data. We consider the known ecology of the species within the vegetation types, and we also analyze the polygon shapes and distributions of shapes.

---

[2] SAGIS and GRASS are being provided by the US National Park Service's Denver Service Center. Customized programming and special adaptations are being provided by the University of California, Davis, Division of Environmental Studies Computer Center.

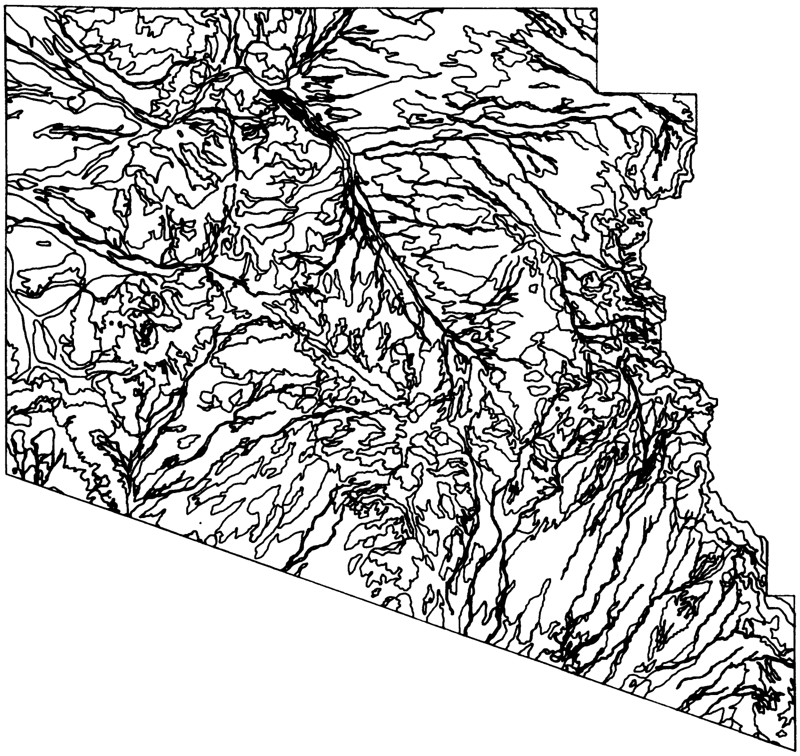
In cases where spatial and temporal characteristics are changing in the region of the monument boundary (Figure 5), we try to determine whether unusually small patches of a vegetation type are due to an anthropogenic disturbance or to a location near the limits of its tolerance to natural environmental conditions. We also examine landscape features to see if the vegetation is restricted to the area by landscape structures or may be encouraged or reduced by certain localized impacts. If, on field examination, the vegetation type's distribution appears to be affected by protection at the administrative boundary (or lack of protection on the other side), these patch sites are considered potentially sensitive and likely to lie within the generated edge.

We can look at temporal effects in several ways. We can look at all vegetation types that stop at the administrative boundary and ask whether the polygons once extended beyond the boundary and thus are fragments, whether the polygons not only extended to the other side but were larger on the outside than on the inside, and whether the fragments have changed size and shape. We determine the consistency of shapes and sizes of polygons within single vegetation-type layers. This approach makes it possible to study the behavior of each vegetation type in the context of additional features, such as landscape.

Where we find abnormalities spatially and temporally associated with the administrative boundary (such as relict populations and intruders), we suggest that the generated edge extends, or is moving, inward. There, associated boundary segments are hypothesized to be sensitive. Final determinations of the condition and importance of the sites to protection are left for the field team conducting the baseline habitat inventory.

This boundary study at Organ Pipe Cactus National Monument is helping test the practicality of a boundary focus for describing the condition of an established nature reserve. Simultaneously, it helps initiate a data base that can be used as the foundation for an operating geographic information system. It focuses management attention on the boundary; for example, on the impact of the boundary on protection, on the location of generated edges (such as with vegetation described here), on segments that appear sensitive, and on future needs to push the generated edges outwardly to or beyond the actual administrative boundary.

Figure 5. Vegetation map of Organ Pipe Cactus National Monument showing shapes (polygons) of all the occurrences of the 27 vegetation types.



Challenges

Challenges remain in integrating the different types of data for practical application. They include coping with variable resolution among data sets, working with both qualitative and quantitative data within the same evaluation, reducing incompatible data sets to common descriptions, and easily modifying the method to handle alternate protection goals or different stages of development for different projects. Many of these struggles will be overcome by those developing GIS technology. So, it leaves us with the principal challenge of determining how to interpret the condition and effectiveness of the nature reserve boundary for protection.

Where we are without funds or high technology, we can work at other levels. We can focus upon how to administer protection so that the boundary is used effectively, anticipating the influences that would undermine its function.

What the model suggests

The boundary model suggests that management pay close attention to localized breakdown (biological leakage points) in either filter of protection or to sites where gradients of change across the generated edge are so steep and narrow that localized collapse of protection is likely. At these locations purchases of additional land may be beneficial. Similarly, in conflicts over adjacent land use, boundary analysis can assist managers to determine where increased cooperation and compromise is possible and necessary.

In cases where present contrast is not great across the administrative boundary but is changing rapidly and in which the direction of change is not favorable to protection, measures can be taken to push the gradient outwardly and reduce the steepness. The choice of location and structure of the buffer zone (e.g., Hiscock 1986) and how it is managed should be based on knowledge of the generated edge as evaluated across more than just ecological variables and more than one class of boundary segments.

Conclusions

Most nature reserves are suffering challenges to their boundaries. Around the world, many nature reserves have shrunk in the face of development, human competition for resources, and changes in political ideologies. To remain, nature reserves must be respected. Enforcement can encourage obedience, but it is better to manage the human interactions in such a way that both the nature reserve managers and the local population see value in developing a buffer of experimentation. Buffer regions established as experimental areas between the core and surrounding regions of biosphere reserves should serve as good examples of constructive boundary management. But, these concepts should be pushed further to make the buffer (or experimental) areas strongly reflect the spatial, natural, and cultural (including economic) heterogeneity along the boundary's legnth.

Acknowledgments

The financial, technical, and administrative support for the boundary research has come from the United States National Park Service (USNPS, National and Western Regional Offices), The US Man and the Biosphere Program (Project 8), Organ Pipe Cactus National Monument, and the University of California, Davis (computer facilities of the Division of Environmental Studies). Computer assistance and consultation has been offered by the USNPS Denver Service Center and the UC Davis Division of Environmental Studies Computer Center. I wish to thank those who are assisting me—Raymond Sauvajot, Stephanie Blume, and Robin Meadows—and those who have reviewed this manuscript for their constructive comments and assistance. The statements herein are solely the responsibility of the author and do not necessarily reflect opinions or policies of the US National Park Service.

References cited

Ambrose, J. P. 1987. Dynamics of ecological boundary phenomena along the borders of Great Smoky Mountains National Park (NSP-CPSU, Institute of Ecology, University of Georgia, Technical Report 34, Athens.

Anadu, P. A., 1987. Progress in the conservation of Nigeria's wildlife. *Biol. Conserv.* 41: 237–252.

Brittingham, M. C., and S. A. Temple. 1983. Have cowbirds caused forest songbirds to decline? *BioScience* 33: 31–35.

Dasmann, R. F. 1988. Buffers, boundaries, and biosphere reserves. *BioScience* 38:487– 489.

Diamond, J. M., K. D. Bishop, and S. vanBalen. 1987. Bird survival in an isolated Javan woodland: island or mirror? *Conserv. Biol.* 1: 132–142.

Field, D. R., and D. Johnson. 1981. Applied and basic social research: a difference in social context. *Leisure Sciences* 4: 269–280.

———. 1983. Interactive process of applied research: a partnership between scientists and park and resource managers. *J. Park and Recreation Administration* 1(4): 18–26.

Forman, R. T., and M. Godron, eds. 1986. *Landscape Ecology.* John Wiley & Sons, New York.

Hiscock, J. W. 1986. Protecting national park system buffer zones: existing, proposed and suggested authority. *J. Energy Law Policy* 7: 35–94.

Keiter, R. B., and W. A. Hubert. 1987. Legal considerations in challenging external threats to Glacier National Park, Montana, USA. *Environ. Manage.* 11: 121–126.

Ives, J. D., and P. Ives. 1987. *Mountain Research and Development: The Himalaya-Ganges Problem.* vol. 7, no. 3.

Janzen, D. H. 1983. No park is an island: increase in interference from outside as park size decreases. *Oikos* 41: 402–410.

Loomis, J. 1987. An economic evaluation of public trust resources of Mono Lake. Institute of Ecology Report No. 30. College of Agricultural and Environmental Sciences, University of California, Davis.

Lucke, T. W. 1986. The National Park Service in law reviews and law journals: a fourth update. *Forum* 5: 14–18.

McCoy, E. D., S. S. Bell, and K. Walters. 1986. Identifying biotic boundaries along environmental gradients. *Ecology* 67: 749–759.

Machlis, G. E., and D. L. Tichnell. 1987. Economic development and threats to national parks: a preliminary analysis. *Environ. Conserv.* 14: 151–156.

MacMahon, J. A. 1979. North American deserts: their floral and faunal components. Pages 21–82 in D. W. Goodall and R. A. Perry, eds. *Arid-Land Ecosystems,* vol. 1. Cambridge University Press, Cambridge, UK.

Myers, N. 1987. Not far afield: U.S. interests and the global environment. World Resources Institute, Washington, DC.

Norton, B. G., ed. 1986. *The Preservation of Species: The Value of Biological Diversity.* Princeton University Press, Princeton, NJ.

Noss, R. F., and L. D. Harris. 1986. Nodes, networks and MUMs: preserving diversity at all scales. *Environ. Manage.* 10: 299–309.

Office of Technology Assessment (OTA). 1986. Technologies to Maintain Biological Diversity. OTA, Washington, DC.

O'Leary, D. 1987. Case studies in protecting parks. *Natural Resources Report* 87-2. US Department of Interior, National Park Service, Washington, DC.

Organ Pipe Cactus National Monument. 1985. Land protection plan. In-house report. Organ Pipe Cactus National Monument, AZ.

Prins, H. H. T. 1987. Nature conservation as an integral part of optimal land use in East Africa: The case of the Masai ecosystem of Northern Tanzania. *Biol. Conserv.* 40: 141–161.

Quinn, J. F. In press. Extinction rates and species richness of mammals in western North American parks. *Biol. Conserv.*

Risser, P. G. 1985. Towards a holistic management perspective. *BioScience* 35: 414–418.

Risser, P. G., and K. D. Cornelison, eds. 1979. Man and the Biosphere. US Information Synthesis Project, MAB-8 Biosphere Reserves. Oklahoma Biological Survey, Norman.

Salwasser, H., C. M. Schonewald-Cox, and R. Baker. In press. The role of interagency cooperation in managing for viable populations. In M. E. Soulé, ed. *Viable Populations.* Cambridge University Press, Cambridge, UK.

Sax, J. L., and R. B. Keiter. 1987. Glacier National Park and its neighbors: a study of federal interagency relations. *Ecol. Law Q.* 14: 207–263.

Schonewald-Cox, C. M. 1983. Conclusions: Guidelines to Management: A Beginning Attempt. Pages 414–445 in C. M. Schonewald, S. M. Chambers, B. MacBryde, and L. Thomas, eds. *Genetics and Conservation.* Benjamin/Cummings Publ., Menlo Park, CA.

Schonewald-Cox, C. M., and J. W. Bayless. 1986. The boundary model: A geographical analysis of design and conservation of nature reserves. *Biol. Conserv.* 38: 305–322.

Schonewald-Cox, C. M., S. M. Chambers, B. MacBryde, and L. Thomas. eds. 1983. *Genetics and Conservation.* Benjamin/Cummings Publ., Menlo Park, CA.

Soulé, M. E. 1986. Conservation biology and the "real world." Pages 1–12 in M. E. Soulé, ed., *Conservation Biology: Science of Scarcity and Diversity.* Sinauer Associates, Sunderland, MA.

———. 1987. *Viable Populations.* Cambridge University Press, Cambridge, UK.

Temple, S. A., and J. R. Cary. In press. Population dynamics of habitat-interior birds in fragmented landscapes. *Conserv. Biol.*

US Department of the Interior (USDOI)/National Park Service (NPS). 1983. Management Program; Organ Pipe Cactus National Monument, Arizona; an addendum to the Natural and Cultural Resources Management Plan, revised June 1983. USDOI/NPS, Organ Pipe Cactus National Monument, AZ.

Usher, M. B., ed. 1986. *Wildlife Conservation Evaluation.* Chapman & Hall, London.

Warren, P. L., B. K. Morteson, B. D. Treadwell, J. E. Bowers, and K. L. Reichardt. 1981. Vegetation of Organ Pipe Cactus National Monument, Technical report no. 8. Cooperative National Park Resources Studies Unit, University of Arizona, Tuscon.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66: 1211–1214.

Wilcove, D. S., and R. M. May. 1986. National park boundaries and ecological realities. *Nature* 324: 206–207.

Wilcox, B. In press. *The Management of Viable Populations: Theory, Application and Case Studies.* Island Press, Washington, DC.

Wilson, E. O. 1988. *Biodiversity.* National Academy Press, Washington, DC.